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PATENT SPECIFICATION

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(19)

(54) IMPROVEMENTS IN OR RELATING TO SOUND-ABSORBING STRUCTURES

(71) We, SHORT BROTHERS & HARLAND LIMITED, a Northern Ireland Company, of PO Box 241, Airport Road, Belfast BT3 9DZ, Northern Ireland, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to sound-absorbing structures and to gas turbine engines including such sound-absorbing structures.

It has previously been proposed to produce a sound-absorbing structure comprising a perforate facing sheet and a parallel imperforate backing sheet with a hexagonal honeycomb core sandwiched therebetween to form a plurality of single Helmholz resonator cells. The mechanism of sound attenuation by such single resonators is well known.

The frequency absorbed by each cell is dependent generally on the depth of each cell and it is clear that in the above previously proposed arrangement, in which all the cells are of the same depth, sound will be absorbed over a narrow range of frequences determined by that depth. If it is required to absorb sound over a broad range of frequences, such as are found within a gas turbine engine, then it is clear that the cell depth must be varied.

This has been achieved in one previously proposed arrangement shown in Figure 1 of the accompanying drawings which is a cross-section of a part of a fan duct of a by-pass gas turbine engine (not shown). A cowl 10 has an inner annular surface 11 which carries an annular sound-absorbing structure 12 surrounding a central axially extending portion of the duct. The structure 12 is formed by a perforate facing sheet 13 and a stepped imperforate backing sheet 14. The space between the sheets 13 and 14 is divided into a plurality of cells by a core structure 15. The cells form a plurality of annular groups of cells with adjacent groups of cells increasing in depth in a down stream direction. The increase in depth causes a decrease between adjacent groups of cells in the frequencies of the ranges sound frequencies absorbed by the groups of cells and so the sound absorbing structure of Figure 1 will absorb sound over a broad range of frequencies.

It is a disadvantage of the structure 12 of Figure 1 that it cannot easily be used as a structural member in the duct because of the stepped nature of the backing sheet 14. The load paths are complex and the structure is difficult to manufacture.

In another previously proposed arrangement for the absorption of sound over a broad range of frequencies, a sound absorbing structure has comprised a perforate facing sheet and a parallel imperforate backing sheet with a core structure therebetween forming with the facing sheet a plurality of side-by-side chambers. Each chamber is divided into two cells by a perforate intermediate member. The facing sheet in such a structure has a constant perforation over its surface and the intermediate members, whether formed separately or as a single sheet, also all have the same perforation. This provides a plurality of double resonators which, as is well-known, exhibit broader band frequency absorption than a single resonator arrangement.

It is a disadvantage of such a previously proposed double resonator that the band width of the absorption is limited and may not be sufficiently wide to absorb the frequencies commonly found in a gas turbine engine.

It is an object of the invention, therefore, to provide a sound-absorbing structure and a gas turbine engine including such a structure in which one or both of the above-mentioned disadvantages are mitigated or overcome.

According to a first aspect of the invention, there is provided a sound-absorbing structure comprising a porous facing sheet and a non-porous backing sheet with a core structure connecting the facing and backing sheets and forming with the facing and backing sheets a plurality of side-by-side resonating chambers, and intermediate porous members each dividing an associated one of the chambers into two cells, the intermediate porous members being so constructed and arranged that adjacent intermediate members or adjacent groups of intermediate members have differing porosities to cause adjacent associated chambers or groups of chambers to absorb sound of differing ranges of frequencies.

Preferably, the porosity of the intermediate members considered together is constant in one direction parallel to the facing sheet but varies in a second direction parallel to said facing sheet but normal to said one direction to vary in said second direction the range of sound frequencies absorbed by adjacent chambers or groups of chambers.

The invention also includes, in a second aspect, a gas turbine engine comprising a by-pass duct through which, in use, air passes from a front fan, and an exhaust duct through which, in use, hot exhaust gases flow from a combustion section of the engine to exhaust, at least one of said ducts being lined with a sound absorbing structure according to the first aspect of the invention.

The following is a more detailed description of some embodiments of the invention, by way of example, reference being made to accompanying drawings in which:—

Figure 2 is a schematic cross-sectional view of one form of sound-absorbing structure;

Figure 3 is a cross-section on the line III—III of Figure 2;

Figure 4 is a side elevation, partially a cross-section of a gas turbine engine according to the second aspect of the invention.

Figure 5 is a cross-sectional view of a part of the fan duct of the gas turbine engine of Figure 4, showing a second form of sound absorbing structure; and

Figures 6 and 7 are similar views to Figure 4 showing third and fourth forms of sound-absorbing structure.

Referring first to Figures 2 and 3, the sound absorbing structure shown therein comprises a perforate facing sheet 20 and a parallel imperforate backing sheet 21 free from discontinuities. These sheets 20, 21 may be of metallic material. A honeycomb core structure 22 divides the space therebetween to form a plurality of side-by-side resonating chambers. An intermediate perforate sheet 25 forms a plurality of porous members each of which divides an associated one of the chambers in the same proportion to form two cells 23, 24 thus forming each chamber into a double resonator.

The perforation of the facing sheet 20 is constant over its surface and is matched to the frequency of the incident acoustic energy and to the ambient conditions surrounding the panel in use. The intermediate perforate sheet 25 has perforations the size of which vary over its surface, but the density of which (i.e. the number of perforations per unit area) is constant. As shown, the perforations are constant in size in one direction parallel to the facing sheet 20 but increase in size in a second direction parallel to said facing sheet but normal to said one direction so that the perforations are larger towards the right-hand end of Figures 2 and 3 and smaller towards the left-hand end. This variation in the size of the perforations is matched to the frequencies to be absorbed so that the intermediate sheet of the double resonator chambers at the right-hand end of the panel, as viewed in Figures 2 and 3, is transparent to sound to give an effective depth corresponding to the total depth of the chambers and absorption of a range of lower sound frequencies. Conversely, the intermediate sheet, at the left-hand end of the panel, as viewed in Figure 2, is impervious to sound, thus giving a resonator formed by the cell 23 and absorption of a range of higher sound frequencies. The intermediate size of perforation between these extremes provides a plurality of broad band resonators which absorb a range of intermediate sound frequencies. It will be appreciated that the number of perforations per unit area of the intermediate sheet 25 could be varied, either by the provision of perforations of constant size and/or by the provision of perforations of variable size.

In this way, a sound absorbing structure is produced in which the band width of frequencies absorbed thereby can be arranged to be wide. In addition, the rectangular cross-section of the structure enables it to carry loads when incorporated in a load bearing assembly. The loads are readily calculated and the structure is easily manufactured.

An example of the use of a structure of the kind shown in Figures 2 and 3 as a load bearing member is shown in Figures 4 and 5. Parts common to Figures 2 and 3 and to Figures 4 and 5 bear the same reference numerals and will not be described in detail. Referring first to Figure 4, a gas

turbine engine 30 is provided with a front fan 31 driven by a combustion and turbine sections 32 of the engine. This section is surrounded by a casing 33 which includes an exhaust 34 for the hot exhaust gases. The front fan is surrounded by an annular cowl 10 which forms an annular passage 27 for air from the front fan.

Referring next to Figure 5, the sound absorbing structure is annular and has a facing sheet 20 just below the level of an inner surface of the cowl 10. The size of the perforations of the intermediate sheet 25 increases in a downstream direction parallel to the axis of the duct. The perforations of both the facing sheet 20 and the intermediate sheet 25 are chosen so that the structure absorbs the characteristic frequencies of sound found in the annular passage 27 in the manner described above with reference to Figures 2 and 3 which may be between 100 cycles per second and 8000 cycles per second.

The facing sheet 20, intermediate sheet 25 and backing sheet 21 all act as load bearing members in the duct. This effects a considerable saving in duct weight over structures which do not bear any load.

Although the perforations of the facing sheet 20 may be calculated to match the frequency of the incident acoustic energy and the ambient conditions, the attenuation contribution of the facing sheet 20 is very sensitive to changes in such energy and conditions. This sensitivity can be moderated by a porous sheet of woven or non-woven organic or inorganic fibres 28 bonded or welded to the perforate facing sheet 20.

Referring next to Figures 6 and 7, parts common to these figures and to Figures 2 and 3 are given the same reference numerals and will not be described in detail. In Figure 6, the backing sheet 21 is conical free from discontinuities and is inclined to the facing sheet 20 and the intermediate sheet 25. Thus the intermediate sheet 25 divides the chambers in different proportions, this gives a greater variation in chamber depth over the structure while still providing a load bearing member. Figure 7 shows a backing sheet 21 which has a smoothly curving surface which is free from discontinuities and increases the depth of the chambers in a downstream direction parallel to the duct axis.

It will be appreciated that a porous sheet of woven or non-woven organic or inorganic fibres may overlie the facing sheet of any of the embodiments of Figures 2, 6 and 7. In addition, or alternatively a similar porous sheet of fibres may overlie the intermediate sheet 25, to decrease the sensitivity of this sheet.

In another arrangement (not shown), the perforate facing sheet 20 and/or the perforate intermediate sheet 25 may be replaced by a sheet of woven or non-woven organic or inorganic fibres with the fibres providing a variable porosity. The facing sheet 20 may be curved or inclined to give desired sound absorption characteristics and it will be appreciated that while the porosity of the intermediate sheet 25 in the structures illustrated in the accompanying Figures 2 to 7 varies in one direction only, the porosity of these sheets may vary in two directions and may have any desired variation over the structure to give a desired sound absorbing performance.

The porosity of the facing sheet 20 whether of metal or fibres, may be varied to accommodate variations in ambient conditions around the panel. For example, the porosity of the facing sheet may increase in a downstream direction; where the facing sheet is perforate this variation may be by variation of the size of the perforations and/or by variation of the number of perforations per unit area of the facing sheet 20. Any of the structures described above with reference to Figures 2 to 7 of the accompanying drawings may be used as a structural load-bearing liner in many parts of a gas turbine engine, for example a jet pipe, a by-pass duct and an intake of a gas turbine engine.

WHAT WE CLAIM IS:—

1. A sound absorbing structure comprising a porous facing sheet and a non-porous backing sheet with a core structure connecting the facing and backing sheets and forming with the facing and backing sheets a plurality of side-by-side resonating chambers, and intermediate porous members each dividing an associated one of the chambers into two cells, the intermediate porous members being so constructed and arranged that adjacent intermediate members or adjacent groups of intermediate members have differing porosities to cause adjacent associated chambers or groups of chambers to absorb sound of differing ranges of frequencies.

2. A structure according to claim 1 wherein the porosity of the intermediate members considered together is constant in one direction parallel to the facing sheet but varies in a second direction parallel to said facing sheet but normal to said one direction to vary in said second direction the range of sound frequencies absorbed by adjacent chambers or groups of chambers.

3. A structure according to claim 2 wherein the porosity of the intermediate members increases in said second direction to correspondingly decrease the range of freqencies absorbed by adjacent chambers in said second direction.

4. A structure according to claim 2 or claim 3 where the intermediate members are formed by portions of a single intermediate sheet located between the facing and the backing sheets, the intermediate sheet extending through each chamber to divide each chamber into two cells.

5. A structure according to claim 4 wherein the intermediate sheet has a porosity which increases gradually in said second direction.

6. A structure according to claim 4 or claim 5 wherein the intermediate sheet divides each of said chambers in the same proportion to form said two cells.

7. A structure according to claim 4 or claim 5 wherein the intermediate sheet divides each of said chambers in different proportions to form said two cells.

8. A structure according to anyone of claims 1 to 7 wherein the porosity intermediate members is provided by perforations and wherein the differing porosities are effected by variation of the size of the perforations and/or by variation of the number of perforations per unit area of the intermediate members.

9. A structure according to claim 8 wherein the intermediate members have woven or non-woven organic or inorganic fibres welded or bonded thereto to modify the acoustic properties of the intermediate members.

10. A structure according to any one of claims 1 to 7 wherein the intermediate members are formed by portions of a single porous sheet of woven or non-woven organic or inorganic fibres, the intermediate porous sheet extending through the chambers to divide each chamber into two cells.

11. A structure according to any one of claims 1 to 10 wherein the facing sheet and the backing sheet are parallel so that all the chambers have the same depth.

12. A structure according to any one of claims 1 to 10 wherein the facing sheet and the backing sheet are so constructed and arranged that the depth of the chambers increases in a predetermined direction parallel to the facing sheet.

13. A structure according to claim 12 when dependent on claim 2 or claim 3 wherein said predetermined direction is the same as said second direction.

14. A structure according to any one of claims 10 to 13 wherein the backing sheet defines a surface which is free from discontinuities.

15. A structure according to claim 12 or claim 13 wherein the facing sheet is a flat sheet and wherein the backing sheet is a flat sheet, said facing sheet and said backing sheet diverging in said predetermined direction.

16. A structure according to claim 12 or claim 13 wherein the backing sheet has a smoothly curving surface whose distance from the facing sheet increases in said predetermined direction.

17. A structure according to anyone of claims 1 to 16 wherein the facing sheet has a porosity which varies over the area of the facing sheet.

18. A structure according to claim 17 when dependent on claim 2 or claim 3 wherein the porosity of the facing sheet varies in a direction which is the same as said second direction.

19. A structure according to claim 18 when dependent on claim 3 wherein the porosity of the facing sheet increases in a direction which is the same as said second direction.

20. A structure according any one of claims 17 to 19 wherein the facing sheet is perforate and wherein the variation in porosity is achieved by variation in the size of the perforations and/or the number of perforations per unit area of the facing sheet.

21. A structure according to claim 20 wherein the facing sheet is overlaid with woven or non-woven organic or inorganic fibres to decrease the sensitivity of the facing sheet to variations in ambient conditions.

22. A structure according to any one of claims 17 to 19 wherein the facing sheet is formed by woven or non-woven organic or inorganic fibres.

23. A structure according to any one of claims 1 to 9 or to any one of claims 11 to 21 except when dependent on claim 10 wherein the structure is made of metal sheets.

24. A sound absorbing structure substantially as herein before described with reference to Figures 2 and 3 or to Figures 4 and 5 or to Figure 6 or to Figure 7 of the accompanying drawings.

25. A gas turbine engine comprising a by-pass duct through which, in use, air passes from a front fan, and an exhaust duct through which, in use, hot gases flow from a combustion section of the engine to exhaust, at least one of said ducts being lined with a sound absorbing structure according to anyone of claims 1 to 24.

26. A gas turbine engine according to claim 25 and including a sound absorbing structure according to claim 2 or claim 3 or any claim appendant to claim 2 or claim 3 wherein said direction normal to said one direction is parallel to but spaced from the axis of the duct which the structure lines.

27. A gas turbine engine according to claim 25 or 26 wherein the backing sheet

forms a load bearing member of the duct.

28. A gas turbine engine according to any one of claims 25 to 27 wherein the intermediate members for load bearing members of the duct.

29. A gas turbine engine substantially as herein before described with reference to Figures 4 and 5 or to Figures 6 or Figure 7 of the accompanying drawings.

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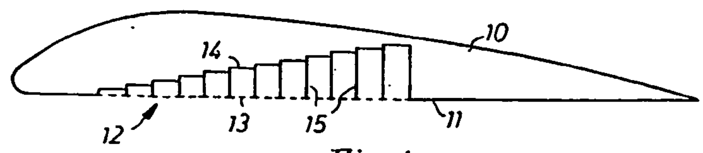

Fig. 1

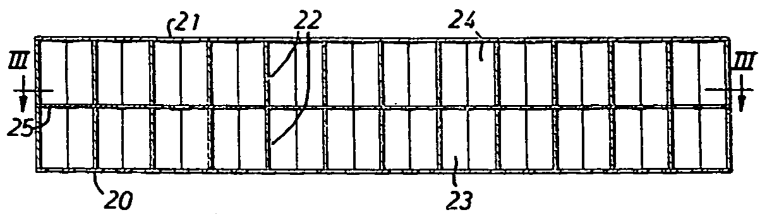

Fig. 2

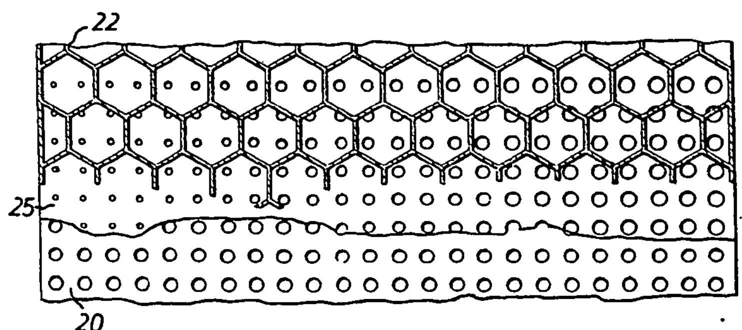

Fig. 3

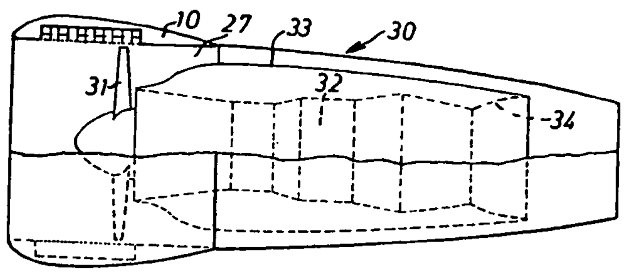

Fig. 4

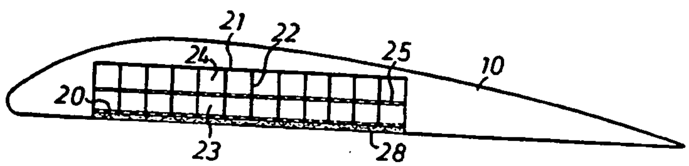

Fig. 5

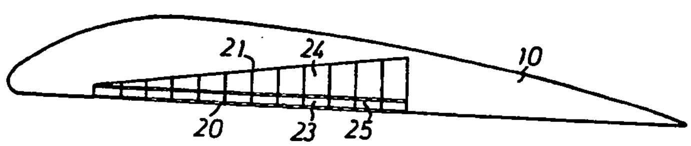

Fig. 6

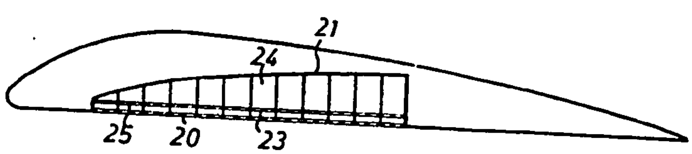

Fig. 7